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Pharyngeal airway morphology in healthy individuals and in obstructive sleep apnea patients treated with maxillomandibular advancement: a comparative study

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Objective. This study investigated the differences in airway morphology between control patients and those with obstructive sleep apnea (OSA) treated with maxillomandibular advancement (MMA) to gain better insight into the beneficial effects of MMA on airway morphology and OSA severity.

Study Design. This retrospective case-control study included preoperative radiographic data gathered for all patients; postoperative radiographic data were gathered for the OSA group. Statistical analysis, including the Student *t* test, and simple linear regression was performed to identify differences in cephalometric and airway variables among the three groups and to associate airway morphology to disease severity.

Results. Twenty-four patients (12 with OSA; 12 controls) treated at the same clinic were included in this study. Statistically significant differences versus control values were found for preoperative total airway volume, postoperative airway length, and both pre- and postoperative airway minimum cross-sectional areas. In general, the untreated OSA airway was anatomically compromised in comparison with controls, whereas the treated airway showed significant morphologic improvements, comparable with the control group values.

Conclusions. MMA produces statistically significant airway improvements for OSA patients, producing airway morphology comparable with that of the controls. However, some degree of residual OSA may still exist. Therefore, factors other than static airway morphology contribute to OSA pathogenesis. (Oral Surg Oral Med Oral Pathol Oral Radiol 2015;119:285-292)

Obstructive sleep apnea (OSA) is characterized by airway collapse and compromised respiration during sleep. The increasing prevalence[1] of this condition, and the negative health consequences[2-4] mean that effective diagnosis and treatment of OSA are critical.

Maxillomandibular advancement (MMA), a well-recognized and successful[5-16] surgical treatment for OSA, attains results comparable with continuous positive airway pressure (CPAP),[17] the gold standard for nonsurgical management of OSA. However, CPAP requires habitual use[18] and has relatively poor patient compliance.[19-21] In contrast, MMA alters the airway morphology permanently,[22-28] which results in long-term improvement of OSA.[8,10,13,15,29]

The airways of patients with OSA are long, narrow, and circular relative to those of healthy individuals.[22,23,25-28,30-32] This has been proposed as the mechanism by which airway resistance is increased and air flow is compromised.[22,26,33-37] As such, several studies have investigated the changes to the ratio of lateral to anteroposterior axial airway dimensions following MMA, but the results have been inconsistent.[22,26,27,32] To relate airway volume with airway length, Schendel et al.[38] established values for the airway index of 1300 healthy individuals. Following MMA, the airway becomes shorter and more voluminous.[22-28] The airway index relates these changes, and the normative values provided by Schendel et al. allow us to investigate whether the airway index has relevance in the pathogenesis of OSA.

Many volumetric studies have documented beneficial morphologic changes to the pharyngeal airway following MMA in patients with OSA.[22,23,26,28] Although the untreated airways in patients with OSA have been studied in comparison with the airways of healthy control patients,[33-35,39,40] limited research has been published on the post-MMA airways of patients with OSA relative to control patients.[22]

The purposes of this study were as follows:

- To gain insight into the craniofacial and airway morphologic factors that vary between patients with

Statement of Clinical Relevance

This study found that the obstructive sleep apneic (OSA) airway treated with maxillomandibular advancement surgery attained morphologic improvements versus preoperative and control airways. Some patients had residual OSA, which indicated that factors other than static airway morphology contribute to OSA pathophysiology.

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OSA and healthy individuals, and this may be predictive of the presence and severity of OSA.
- To compare the post-MMA sleep apneic airway morphology to healthy airway morphology.
- To evaluate the relevance of the lateral−anteroposterior (LAT/AP) ratio to the severity of OSA to determine if variation in this parameter can have pathologic consequences for the airway.

METHODS AND STUDY DESIGN/SAMPLE

This study was approved by the Ethics Review Board of the Ottawa Hospital Research Institute. This retrospective, case-control study comprised patients who were diagnosed with OSA and treated with MMA between 2010 and 2014. Inclusion criteria for patients with OSA included diagnosis of OSA by overnight laboratory polysomnography; clinical and fiberoptic nasopharyngoscopic examination; sufficiently healthy to undergo MMA surgery; site of obstruction in the oropharynx; body mass index (BMI) less than 40 kg/m^2; between the ages of 18 and 65 years; access to pre- and postoperative lateral cephalography and cone beam computed tomography (CBCT); class I and II dental occlusions; and intolerance to CPAP with a minimum 3-month trial.

Patients without OSA who were seen for orthognathic surgery were included as control patients. Inclusion criteria for control patients included: BMI less than 40 kg/m^2; ages between 18 and 65 years; access to preoperative radiography; and class I and II dental malocclusions. Exclusion criteria were symptoms or history of OSA; previous upper airway surgery; and class III dental malocclusion.

Surgery

LeFort I maxillary osteotomy and bilateral sagittal split ramus osteotomy with rigid internal fixation were performed for all patients with OSA by the same surgeon (K.J.B.). Seven patients received counterclockwise rotation of the maxillomandibular complex; two patients also received cosmetic genioplasty, which excluded the genial tubercles. Seven patients had previously undergone airway surgery.

Data

Pre- and postoperative overnight laboratory polysomnograms were obtained for each patient with OSA. OSA was not present in the control patients; therefore each control subject was assigned an apnea−hypopnea index (AHI) score of 3 (halfway between 0 and mild OSA).

Lateral cephalograms and CBCT scans (Planmeca Promax 3-D Mid, Helsinki, Finland) were obtained for the OSA group immediately preoperatively and between 3 and 12 months postoperatively. CBCT scans were acquired for the control patients. Patients were asked to avoid swallowing during CBCT image acquisition. The lateral cephalograms were uploaded to Dolphin 11.7 imaging software (Dolphin Imaging and Management Solutions, Chatsworth, CA) for analysis, as were the CBCT scans in the Digital Imaging and Communications in Medicine format. The Cephalometrics for Orthognathic Surgery (COGS) analysis was used for the evaluation of the lateral cephalograms.

The sagittal slice containing the incisive canal was used for measurements on the CBCT scans; measurements were taken relative to the natural head position. Boundaries of the pharyngeal airway under investigation were the posterior nasal spine superiorly; the tip of the epiglottis inferiorly[41]; the lateral and posterior pharyngeal walls, and the base of the tongue laterally. The nasopharynx was defined as “the region from the posterior nasal spine to the tip of the uvula”; the oropharynx was delimited superiorly by the tip of the uvula and inferiorly by the tip of the epiglottis.[26,28]

Parameters of interest

The cephalometric parameters investigated in the present study included mandibular plane angle (MP); occlusal plane angle (OP); maxillary protrusion (N-A); mandibular protrusion (N-B); chin protrusion (N-Pg); and posterior airway space (PAS).

CBCT parameters of interest were volume (VOL) in cubic centimeters (cm^3) of the total airway (nasopharynx and oropharynx); airway length (AL) in millimeters (mm); airway index (AI, ratio of airway VOL [cm^3] to AL [mm])[38]; minimum cross-sectional area (minCSA) in squared millimeters (mm^2) of the total airway and of each pharyngeal compartment; lateral (LAT) and anteroposterior (AP) dimensions of minCSA (mm); and the lateral to anteroposterior ratio (LAT/AP) at minCSA.

Statistical analysis

Statistical analysis was performed using Microsoft Excel version 14.4.3 (Microsoft Corporation). Student *t* tests were used to evaluate for significant differences in craniofacial morphology and airway dimensions between the OSA (pre- and postoperative) and control groups. Simple linear regression was used to correlate airway morphology to the AHI. A *P* value less than .05 was considered statistically significant.

RESULTS

Twelve patients (10 male, 2 female) with OSA and 12 control patients (6 male, 6 female) were included in the present study. Descriptive patient information is

Table I. Patient demographic data

	Preoperative OSA	*Postoperative OSA*	*Control*
	Mean ± SD	*Mean ± SD*	*Mean ± SD*
Age	42.75 ± 13.03	44.17 ± 12.32	43.17 ± 7.72
Gender	10 M: 2 F	10 M: 2 F	6 M: 6 F
BMI	30.35 ± 4.10	29.44 ± 3.89	29.21 ± 3.41
AHI	47.77 ± 26.06	7.57 ± 5.97	<5

OSA, obstructive sleep apnea group; *SD*, standard deviation; *M*, male; *F*, female; *BMI*, body mass index; *AHI*, apnea−hypopnea index.

summarized in Table I. Age and BMI did not differ significantly between the OSA and control groups ($P > .05$).

Maxillary advancement for the OSA group was 8.08 ± 2.71 mm, and mandibular advancement was 11.00 ± 2.45 mm. Seven patients were treated with counter-clockwise rotation (−4.93 ± 0.82 degrees), and the remaining five patients received neutral or clockwise rotation (3.31 ± 1.06 degrees). The AHI of the OSA group improved from 47.77 ± 26.06 events per hour preoperatively to 7.57 ± 5.97 events per hour post-operatively ($P < .01$).

Following surgery, airway VOL and AI increased significantly ($P < .05$ and $P < .001$, respectively). PAS also increased ($P < .001$), whereas AL shortened ($P < .001$). Total airway minCSA, LAT, and AP dimensions all increased postoperatively ($P < .001$), whereas the LAT/AP ratio decreased ($P < .05$). VOL of the naso-pharynx and oropharynx were greater following MMA ($P < .05$). The minCSA increased significantly in both the nasopharynx ($P < .001$) and the oropharynx ($P < .01$). The LAT and AP dimensions of the nasopharynx increased ($P < .001$), and the LAT/AP ratio decreased postoperatively ($P < .05$). The LAT and AP dimensions of the oropharynx also increased ($P < .01$), whereas the change in the LAT/AP ratio was not significant ($P = .460$).

Craniofacial characteristics and airway dimensions of the OSA and control groups are summarized in Table II. Mandibular and occlusal plane angles did not differ significantly ($P > .05$) between the control and OSA groups. According to the COGS analysis, maxillary protrusion was significantly greater in the treated OSA patient group (4.16 ± 4.41 mm) compared with the untreated OSA (−3.61 ± 5.73 mm; $P < .001$) or control groups (−6.08 ± 3.41 mm; $P < .001$). Similarly, mandibular and chin protrusions were greater postoperatively in the OSA group (1.03 ± 8.35 mm and 2.69 ± 11.15 mm, respectively) than preoperatively in the OSA group (analysis 9.35 ± 10.20 mm and −8.51 ± 12.02 mm, respectively; $P < .001$) and the control group (−15.26 ± 6.52 and −13.94 ± 7.96, respectively; $P < .001$). Although the differences were not statistically different, the control group was relatively more bimaxillary retrusive compared with the OSA group preoperatively.

Preoperative VOL was significantly less ($P < .05$) in the OSA group than the VOL of the control group, whereas the postoperative VOL of the OSA group did not differ significantly from the control VOL. The AL of the untreated OSA group was similar to the control group, whereas it was significantly shorter ($P < .05$) in the treated OSA group (Figure 1). The AI of the control group was significantly greater than that of the preoperative OSA group ($P < .05$) and less than that of the postoperative OSA group ($P < .05$). Similarly, the total airway minCSA, AP, and PAS were greater in the control group than in the preoperative OSA group ($P < .05$) and less than the postoperative OSA group ($P < .01$). The LAT was narrower in the untreated OSA group ($P < .05$), with no significant difference found in the LAT dimension of both the treated OSA and control groups. Although the LAT/AP ratio decreased significantly in the postoperative period, neither the pre- nor postoperative LAT/AP ratios differed significantly from those of the control patients.

The volume of the nasopharynx was less ($P < .05$) in the preoperative OSA group, whereas there was no difference between the postoperative and control VOL. The minCSA of the control group was greater than that of the preoperative OSA group ($P < .05$) and less than that of the postoperative group ($P < .05$). Similarly, the AP distance in the control group was greater than in the preoperative OSA group ($P < .05$) and shorter than the postoperative OSA group ($P < .01$). However, neither the nasopharyngeal LAT nor the LAT/AP ratio of the control group was statistically different from the pre- or postoperative OSA groups.

In the oropharynx, the VOL, LAT, and LAT/AP ratio of the pre- and postoperative OSA group did not differ significantly from those of the control group. The minCSA and AP of the untreated OSA group were also not significantly different from those of the control group; however, both dimensions were significantly greater in the postoperative OSA group ($P < .01$).

Correlation analysis revealed a significant association between the AHI and the PAS ($r = −0.40$; $P < .05$) and between the AHI and the total airway LAT dimension ($r = −0.35$; $P < .05$). Correlation between the AHI and the LAT dimension of the nasopharynx approached significance ($r = −0.33$; $P = .052$); however, this relationship was not significant at the level of the oropharynx.

DISCUSSION

In the present study, the untreated OSA group and the control group of patients presented with relatively ret-rusive craniofacial profiles, according to the COGS analysis. The profiles of the treated OSA group were

Table II. Craniofacial and airway morphologic parameters in comparison to the control group

	OSA (preoperative)	OSA (postoperative)	Control
	Mean ± SD	*Mean ± SD*	*Mean ± SD*
Cephalometrics:			
MP	26.53 ± 11.60	24.18 ± 9.14	27.57 ± 8.18
OP	8.15 ± 8.05	3.32 ± 6.43	8.48 ± 5.84
N-A	−3.61 ± 5.73	$4.16 \pm 4.41^{\ddagger\phi\Delta}$	−6.08 ± 3.41
N-B	−9.35 ± 10.20	$1.03 \pm 8.35^{\ddagger\phi\Delta}$	−15.26 ± 6.52
N-Pg	−8.51 ± 12.02	$2.69 \pm 11.15^{\ddagger\phi\Delta}$	−13.94 ± 7.96
Total airway:			
VOL	$9.68 \pm 3.81^{*\Delta}$	17.4 ± 7.51	13.5 ± 4.4
AL	55.81 ± 5.51	$48.52 \pm 7.05^{*\phi\Delta}$	56.14 ± 7.41
AI	$0.17 \pm 0.06^{*\Delta}$	$0.36 \pm 0.13^{*\Delta}$	0.24 ± 0.06
minCSA	$82.56 \pm 52.70^{*\Delta}$	$247.38 \pm 104.92^{\dagger\Delta}$	141.68 ± 61.38
AP	$4.33 \pm 2.34^{*\Delta}$	$10.60 \pm 3.69^{\dagger\Delta}$	6.68 ± 2.03
LAT	$16.73 \pm 5.17^{*\delta\Delta}$	23.98 ± 5.11	21.70 ± 5.14
LAT/AP	4.64 ± 2.62	2.58 ± 1.38	3.43 ± 0.84
PAS	$6.60 \pm 2.54^{*\Delta}$	$13.13 \pm 3.30^{\dagger\Delta}$	8.94 ± 2.46
Nasopharynx:			
VOL	$6.4 \pm 3.0^{*\delta\Delta}$	11.3 ± 6.5	10.0 ± 3.3
minCSA	$101.69 \pm 77.16^{*\Delta}$	$252.28 \pm 107.70^{*\Delta}$	168.23 ± 70.46
AP	$4.71 \pm 2.83^{*\Delta}$	$10.55 \pm 3.76^{\dagger\Delta}$	7.02 ± 2.01
LAT	17.87 ± 6.34	24.26 ± 5.07	22.70 ± 5.43
LAT/AP	4.63 ± 2.62	2.62 ± 1.37	3.38 ± 0.77
Oropharynx:			
VOL	3.3 ± 1.3	6.2 ± 4.6	3.6 ± 1.6
minCSA	133.38 ± 57.33	$318.71 \pm 153.87^{\dagger\phi\Delta}$	174.02 ± 62.60
AP	8.68 ± 2.33	$13.35 \pm 3.81^{\dagger\phi\Delta}$	8.75 ± 2.31
LAT	18.72 ± 5.16	27.74 ± 8.21	22.48 ± 5.97
LAT/AP	2.33 ± 0.93	2.16 ± 0.58	2.72 ± 0.92

OSA, obstructive sleep apnea group; *SD*, standard deviation; *MP*, mandibular plane angle (°); *OP*, occlusal plane angle (°); *N-A*, maxillary protrusion (mm); *N-B*, mandibular protrusion (mm); *N-Pg*, chin protrusion (mm); *VOL*, volume (cm^3); *AL*, airway length (mm); *AI*, airway index (cm^3/mm); *minCSA*, minimum axial airway cross-sectional area (mm^2); *AP*, anteroposterior dimension at minCSA (mm); *LAT*, lateral dimension at minCSA (mm); *LAT/AP*, LAT to AP ratio.

Note: All *P* values are the results of a Student *t* test with the control group.

$^*P < .05$.

$^\dagger P < .01$.

$^\ddagger P < .001$.

Δ versus controls.

ϕ versus preoperative OSA group.

δ versus postoperative OSA group.

significantly less retrusive. Taking into account that a retrusive craniofacial profile is reportedly predictive of OSA,[40,42-44] it is interesting that the patients of the present study with the greatest bimaxillary retrusion were not the patients with untreated OSA but, rather, the control patients. Since the control group's craniofacial anatomy was slightly more bimaxillary retrusive than the untreated OSA group, it would be expected that the airways of the control group would be anatomically compromised relative to those of the OSA group. In contrast, the airways of the untreated OSA group were more anatomically compromised, indicating that craniofacial profile may not reliably predict the presence of OSA.

OSA severity has been associated with increased airway length.[34,35,45,46] The preoperative AL of the OSA group in the present study was 55.81 mm, which significantly decreased postoperatively to 48.52 mm. The AL of the control group did not differ significantly from the pretreatment OSA group (56.14 mm versus 55.81 mm), whereas other studies have reported significantly longer airways in patients with OSA.[34,35] Similarly, a study[47] of patients with OSA and snorers did not find a difference in the airway lengths between the two groups; however, inclusion of snorers with an AHI score of 10 or less may have affected the validity of these findings. In contrast to the findings of Abramson et al.,[22] who reported that the postoperative airways of the patients with OSA were still longer than those of the control patients, the postoperative AL in the present study was significantly shorter than that of the control group. Additionally, AL did not correlate to the AHI in the present study. Although AL is a contributing factor to airway resistance, according to Poiseuille's law,[22,26,34,35,48] the

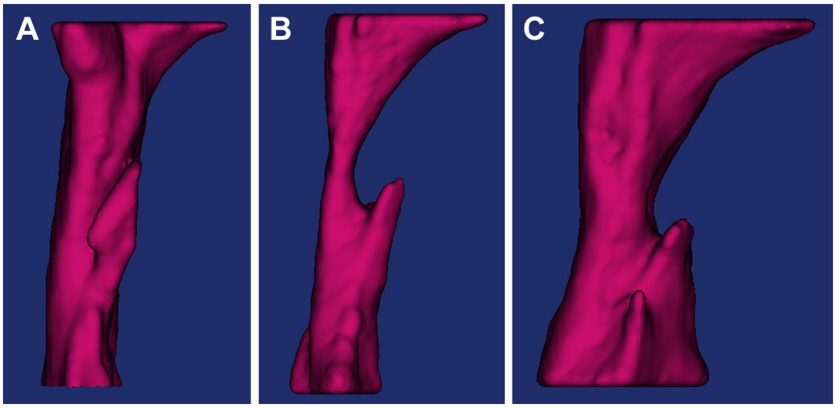

Fig. 1. Pharyngeal airway anatomy. The airways of the control patients (**A**) were wider and more voluminous than the airways of the untreated OSA patient group (**B**). The airways of the treated OSA patient group (**C**) were shorter, wider, and longer anteroposteriorly compared with the airways of the control group.

findings of the present study suggested that an elongated airway may not necessarily be pathognomonic for OSA.

Total airway VOL in the control group was 13.5 ± 4.41 cm^3. Similarly, previous airway studies[34,38,49] of healthy individuals found airway VOL to be between 12.30 and 15.59 cm^3 when similar boundaries were used to define the airway. The airway VOL in the untreated OSA patient group of the present study was 9.68 ± 3.81 cm^3, which was significantly smaller than the treated airway (17.4 ± 7.51 cm^3), and the airway of the control patients (13.5 ± 4.4 cm^3). By comparison, previous studies have also reported significant improvement in airway VOL following MMA.[22,24-28,50,51] Conflicting reports with regard to the size and shape of a healthy airway versus that in untreated OSA are found in the literature.[22,33,34] Despite the different boundaries used to delimit the airway among the studies, the pre- and postoperative airway VOLs of the present study are in agreement with the range of VOLs that have been found for patients with OSA preoperatively (8.0-17.1 cm^3) and postoperatively (10.9-23.2 cm^3) in numerous studies.[22,27,28,31,34]

The AI of the control group was 0.24 in the present study, similar to the AI of 0.22 established by Schendel et al.[38] in a study of 1300 healthy individuals. By contrast, the AI of the OSA group in the present study was significantly less than that of the control group preoperatively (AI = 0.17), and greater postoperatively (AI = 0.36). The combination of a smaller airway VOL preoperatively and shorter AL postoperatively likely accounts for the significant difference in the AI between the OSA and control groups. Although similar changes to the airway have been reported by other researchers,[22,26-28] the AI is not a widely used parameter of airway morphology. Limitations in the number of patients seen for OSA resulted in a small sample size for the present study. Nevertheless, statistical significance was still achieved. However, further research with a larger sample size is warranted to investigate the sensitivity and specificity of this measure and to assess its value in planning treatment for the general OSA population.

PAS less than 11 mm[43] has commonly been accepted as a cephalometric predictor for the presence of OSA. In the present study, the PAS of the OSA group increased from 6.60 ± 2.54 mm preoperatively to 13.13 ± 3.30 mm postoperatively, similar to the findings of a recent meta-analysis.[13] However, many surgical studies have reported improvement in OSA, with the postoperative PAS less than 11 mm.[10,15,29,52,53] On the basis of these findings and taking into consideration that the control group had a PAS of 8.94 ± 2.46 mm in the present study, it is plausible that the value of the PAS predictive of a normal airway may be less than 11 mm. The PAS is an ambiguous variable, which lacks consistent anatomic landmarks; as such, many definitions[9,13,17,53-56] for the PAS exist, and this restricts comparison of results between studies. Although a relationship between improvement in the PAS and OSA severity was found in the present study, findings in the literature are not consistent with regard to this relationship.[10,13,29,53] With the advent of CBCT providing a more accurate[57,58] representation of the airway, a more consistent parameter than the PAS should be used to measure AP retroglossal narrowing, which would facilitate effective comparison between studies and assessment of the relationship to OSA severity.

The LAT/AP ratio of the total airway and of each pharyngeal compartment decreased postoperatively in the present study. However, the change to the LAT/AP ratio was only significant for the total airway and in the nasopharynx. The airway generally became more circular postoperatively; however, it still remained elliptical in shape. Considering the numerous findings in

favor of an elliptical shape,[26,30,31,34,37,39,49,59] it is unlikely that a spherical airway[60] would benefit the patients with OSA. However, given that the total airway and the nasopharyngeal LAT/AP ratio of the present study became more spherical postoperatively, it is possible that an optimal LAT/AP ratio exists, in which there is a beneficial interplay between a stable, circular airway[60] and an elliptic airway.

In keeping with the assertion of the benefits of an elliptic airway, one study[48] proposed that airway stability was more greatly influenced by the relative, rather than the absolute, magnitude of the airway dimensions. However, there was no significant difference between the pre- or postoperative LAT/AP ratios of the OSA group versus the control group at any level of the airway in the present study. Furthermore, Poiseuille's law states that resistance is inversely proportional to the fourth power of the radius. Thus, alteration in the absolute magnitude of the airway dimensions would result in substantial changes to airway resistance. Correspondingly, no association between the LAT/AP ratio and the AHI was found in the present study. However, a significant inverse correlation between the LAT dimension of the total airway and the AHI was found, and this has been reported elsewhere.[48]

No difference was found in the LAT/AP ratios between groups in the present study, whereas the absolute magnitude of the preoperative LAT and AP dimensions were significantly smaller than in the control and postoperative airways. However, the LAT and AP dimensions of the postoperative airway resembled those of the control airway. Previous studies[27,33,34,49] have reported normal LAT and AP values to be 16.2 to 24.2 mm and 7.8 to 10.9 mm, respectively. Consistent with these findings, the LAT and AP dimensions of the control group in the present study were 21.70 $\pm$ 5.14 mm and 6.68 $\pm$ 2.03 mm, respectively. Similarly, the LAT dimension of the treated OSA group was 23.98 $\pm$ 5.11 mm, and the AP dimension was 10.60 $\pm$ 3.69 mm. Thus, the LAT and AP dimensions of the postoperative OSA airway resemble those of healthy persons.

In consideration of the present findings and the conflicting reports in the literature, the validity of the LAT/AP ratio may be questionable. However, as previously proposed by Fairburn et al.,[32] further research with a larger patient population would be warranted to determine whether an optimal LAT/AP ratio exists. More importantly, further research should focus on the absolute magnitude of the airway dimensions that are predictive of OSA and on the relationship of MMA hard tissue surgical advancement to the gain in airway dimensions.

It is important to note that CBCT captures a static image of a dynamic structure. Thus, dimensions of the airway may have slight variations, depending on the respiratory phase[61,62] and head position[63] at the time of image capture. An exciting newer form of imaging, cine magnetic resonance imaging (CineMRI), which provides dynamic imaging information throughout the active respiratory phases, is now being investigated,[64] but its availability remains limited.

Several limitations in the present study must be mentioned. The retrospective study design, small sample size, wide age distribution, and dissimilar gender distribution, have all limited the strength of its conclusions. In addition, neither CBCT scans nor overnight polysomnograms were obtained at uniform times postoperatively, which may have caused the timing of the imaging and polysomnographic investigations to yield differing results. The potential impact of the respiratory cycle on airway imaging outcomes must be considered when evaluating airway morphology. In addition, the control group did not undergo formal overnight polysomnography; rather, the subjects were chosen on the basis of absence of symptoms and lack of personal history of OSA. However, it is possible that these subjects may have had asymptomatic OSA.

Given that the numerous airway parameters of the postoperative OSA treatment group of the present study superseded the values of the control group and that some residual OSA still remains within this patient population, it is likely that the static airway morphology is not the only factor that contributes to OSA. The airway is a dynamic biologic structure, subjected to various hormonal[65,66] neuromuscular,[67,68] and biomechanical[38] influences, which can also play a role in the pathophysiology of OSA. Nonetheless, MMA provides anatomic or structural improvement of the pharyngeal airway in patients with OSA, but other contributing factors must also be considered to influence OSA presence and severity.

CONCLUSIONS

MMA is an effective surgical approach to the management of OSA, as it helps reduce disease severity. Surgical advancement of the maxillomandibular complex substantially improves the anatomically compromised airway of patients with OSA, restoring the airway's anatomy closer to that of the normal population. However, some residual OSA remains in many patients postoperatively, which leads us to the conclusion that factors other than static airway anatomy contribute to the pathogenesis of OSA.

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